Yogurt based food: 'Soy yogurt drink with kiwi Flavour'

Unit III: Defining product and process specifications

Group B

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Executive Summary

The main goal of Unit III was to develop and optimize the final product defining the product and process specifications. This was achieved by developing the process and equipment flowchart according to legislation specifications and by conducting consumer sensory and descriptive analysis. The process flowcharts have been created for both laboratory and industrial scale. In addition, the factory layout for the production process has been designed. Also, the required equipments for the processing in both scales have been selected. In the industrial process, the equipments were chosen according to the production capacity per day. For the production of 10 000 units per day, where the unit is defined as 250 ml in a single bottle, the raw materials needed has been estimated as following: cow's milk around 1t, soy milk around 2t, kiwis around 0.8t, sugar around 0.25t and water more than 0.5t . Moreover, the factory layout was designed to get brief idea about principles to be followed in industry for hygiene and safety.

After defining the technical specifications, experimental design was used to conduct product and process optimization. Sensory consumer and descriptive analysis was followed in order to determine which factor has a significant effect on responses. More particularly, a screening experiment was carried out to determine the consumer acceptability and preference against the product, so that the most acceptable product could be found out and the optimum process could be determined. The experiment was divided into two sessions with 16 samples and 32 untrained assessors. Four factors (cow's yogurt, sugar, kiwi juice, water) were examined into two levels i.e lower and upper level. The data was statistically analyzed using the R project and the response surface methodology. The results indicated that higher levels of both sugar and water and lower levels of kiwi juice and cow's yogurt are preferable. Based on these results, an optimization experiment with nine samples was conducted with the help of 54 untrained assessors in order to minimize the percentage of cow's yogurt and maximize the percentage of kiwi. These two factors were examined in three levels (% kiwi juice: 8, 10, 12, % cow's yogurt: 7.2, 14.7, 22.2). On the other hand, the percentage of both sugar and water was constant at 10% and 20% respectively. The results concluded that the best formulation for the percentage of kiwi juice and cow's yogurt was at 14.5% and 9% respectively. The best formulation for the percentage of sugar (10%) and water (20%) was determined from the screening experiment.

Hence, the final product will be manufactured according to the process specifications, using specified raw materials, ensuring that the product should be always the same and comply with European and UK legislation such as FSA, Codex Alimentarius Commission. The raw material could be provided from supermarket in lab scale. In conformance to the calculations that have been done for the laboratory scale, production of 1000g of 'Soya yogurt drink with kiwi flavour'needs 14.5 % (145gm) of cow's yogurt, 47.5% (475 gm) of soy yogurt, 20% (200gm) of water, 9% (90gm) of kiwi juice and 10%(100gm) of sugar. More study needs to be done on primary, secondary and tertiary package.

In the next Unit, optimization of the product will be continued in order to achieve higher scores. Also, a commercial product test should be conducted to ensure that the final product meet the consumer expectations. In addition, shelf life and the factors affecting it will be investigated in combination with legislation and GMP, GHP, HACCP and quality control procedures.

Task 1: Develop process and equipment flowcharts with description of the whole production process

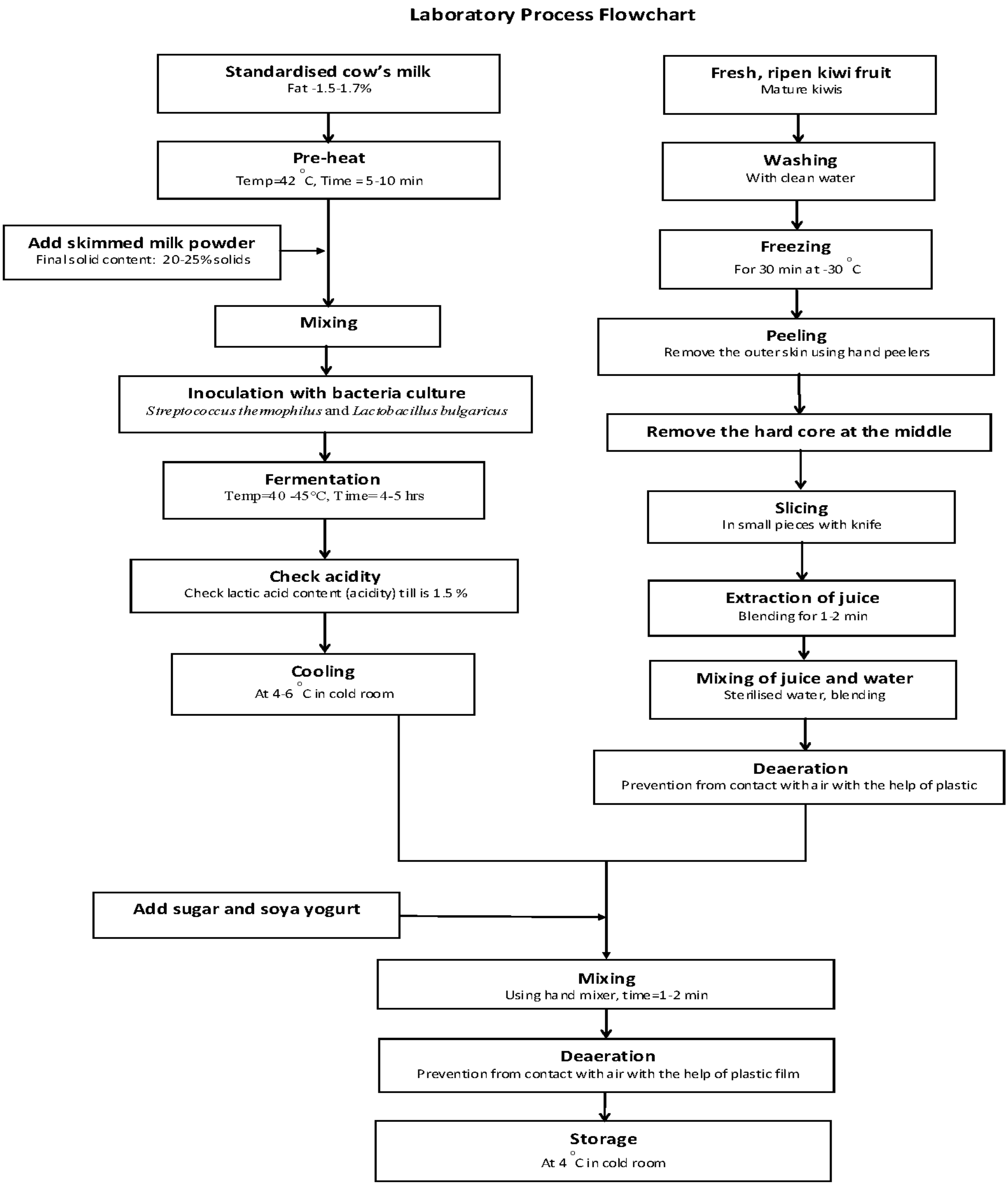


Figure 1 Laboratory flow chart

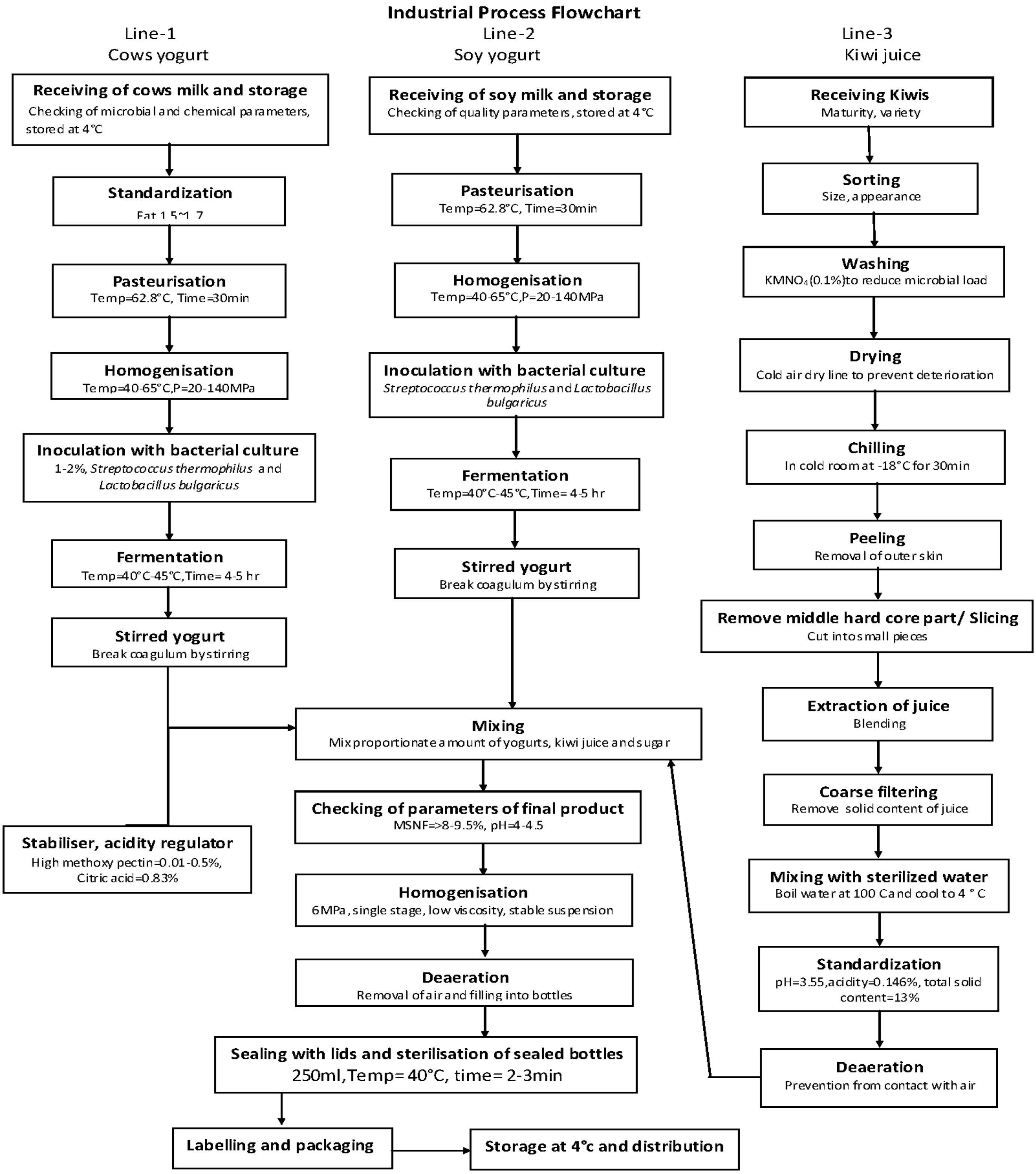


Figure 2 Industrial flow chart

Description of Laboratory Process

Fermentation of cow's yogurt

Standardised cow's milk

The fermentation process begins with the standardised cow's milk which is bought directly from the supermarket. The milk should be semi-skimmed of 1.5-1.7 % fat.

Pre-heat

In this step, the milk is pre-heated at 42 ^{0}C for 5 t-10 minutes in order to destroy lipase activity.

Add skimmed milk powder and Mixing

The skimmed milk powder is mixed with the sterilised milk. The resulting mix should contain 20-25% solids.

Inoculation with bacteria culture

The culture consisting of Streptococcus thermophilus (ST) and Lactobacillus delbrueckii subsp. Bulgaricus, is transferred aseptically to the mixture of milk and skimmed milk powder.

Fermentation

The fermentation process holds around 4-5 hours at 40-45 ^{0}C.

Check lactic acid content (acidity) till is 1.5 %

During the fermentation, the lactic acid content has to be checked regularly till is 1.5 %. In this point, the fermentation has been finished.

Cooling

The fermented product is placed to the cold room to cool down, at 4-6°C.

Kiwi juice extraction

Fresh kiwi fruit

The kiwis using for the juice extraction are bought directly from the supermarket. The soft and mature kiwis should be chosen, since maturity is a determinative factor in the quality of kiwi juice and in the taste of final product as well.

Washing

Kiwis have to be washed with clean running water in order to remove any impurities and the 'small hair' on their skin.

Freezing

About an hour before the fermentation process be accomplished, the washed kiwis are put into the freezer for 30 minutes at -18 0C. This affects dramatically the time of peeling and also the protection of seeds breaking during the extraction of the juice.

Peeling

After the 30 minutes, the outer skin of the kiwis is removed using hand peelers.

Remove the hard core at the middle

The middle hard core is removed from the peeled kiwis since it is very bitter and quite hard to break during the juice extraction.

Slicing

In this step the kiwis are sliced into small pieces in order to reduce the time of the juice extraction as well as to make the process more effective.

Extraction of juice

The small kiwi pieces are placed into a blender for juice extraction.

Mixing of juice and water

The right portion of sterilised water is added in the kiwi juice and both of them are mixed in the blender for 1-2 minutes. The water should be previously boiled and cool down to 4^{0}C in the cold room. The addition of water affects the thickness of the final product, making it thinner and consequently more drinkable.

Deaeration

The juice is collected into a plastic container and is covered with plastic film in order to be protected from oxidation and prevents any alteration in the taste of the final product.

Add soya yogurt and mixing

The proportionate cow's yogurt and the diluted kiwi juice are then mixed with the proportionate soya yogurt and sugar. The soya yogurt is bought directly from the supermarket which is of brand "Alpro soya". All the ingredients are mixed for 1-2 minutes using a hand mixer.

Storage

The final product is kept in the cold room at 4 ^{0}C, covered by a plastic film to protect from oxidation.

Description of Industrial process

Soy yogurt drink with kiwi flavour production takes place continuously on industrial scale. The key components of drink i.e. yogurt from cow's milk, soy yogurt from soy milk and kiwi juice are prepared at the same time at three different lines. Stirred type of yogurt is needed for yogurt drink. As preparation of kiwi juice takes short time than yogurts, it is stored at chilled temperature after preparation until yogurts are ready. First of all Line 1 and line 2 i.e. yogurt from cow's milk and soy yogurt from soy milk is explained together as processing steps for both products are identical then its followed by kiwi juice preparation.

Yoghurt lines 1 and 2

Receiving of milk and storage

For the production of yogurt drink on industrial scale, thousands of litres of milk are processed everyday. Upon arrival of the milk tanker at the dairy, it enters a covered special reception area. Nevertheless, arrival of soy milk could be in different source. A technician from the quality assurance department checks the temperature of the milk and draws the representative sample which is analysed for sediments, antibiotic residues, somatic cell count, protein, fat content. During this procedure, the technician also checks the odour of the milk and records if any off odours are detected. If all tests meet standards set by the dairy, the milk is then unloaded from the tanker. The quality of soy milk is also checked for microbial count and for beany flavour from soybean. After discharging the milk, the special cleaning of tank needs to be done. The raw milk is then stored in large vertical tanks known as silos. These silos have capacities of 25,000-1, 50,000 litres. The silos have methods of agitating milk to prevent gravitational fat separation. Milk storage silos are cleaned in place and visual inspections of the interior surface for any problems are also conducted periodically. It is recommended that silos be emptied and cleaned at regular intervals. The temperature of the milk in the silo has to be maintained at 4°C or below. The raw milk in the silos is further processed (Chandan, 2006).

Standardization

Standardization is done in cow's milk only. The fat content of milk varies according to source and season but in yogurt the level is prescribed by consumer taste. Some or most of the fat is removed from milk as per the requirement. The separation of cream from milk is achieved in cream separator. Accuracy of the process depends upon the type of equipment and efficiency of fat separation obtained. The fat content of skimmed milk is between 0.05-0.07g/100g. Solid content is increased to 16% and MSNF is increased to 11-14%. This is accomplished either by evaporating some of water or adding concentrated milk or milk powder. Evaporation is done in soy milk as well on order to increase solid content. Improving the solid content improves the nutritional value of yogurt, makes it easier to produce firmer yogurt and improves stability of milk (Chandan, 2006).

Pasteurisation

Pasteurisation is needed to kill all pathogenic micro-organism. It is continuous process in industries. In this process standardised milk is heated to 62.5°C-62.8°C for 30min. Nonetheless, soy milk is heated to 62.5°C for 6min. Yogurt manufacture necessitates the holding of milk for longer time in order to denature the whey proteins and thus improves gel strength of yogurt. The effect of heat treatment on milk is to reduce the rate of deterioration due to microbial and enzymic action. In addition, milk may look whiter and appear more viscous, with appreciable flavour changes and decrease in nutritive value. The effectiveness of pasteurization is estimated by assaying for an enzyme

phosphatise. Regenerative preheating is an energy saving step in pasteurisation. In pasteurisation cold milk is preheated and hot milk is cooled simultaneously to 43-45°C (Chandan, 2006).

Homogenization

It is process of reducing the size of fat globules. Homogenization prevents creaming. Cold milk cannot be homogenised efficiently because the milk fat still is solid. The size of the fat globules after homogenization depends upon the temperature of the milk during homogenization and the pressure used. With increase in temperature the degree of dispersion increases rapidly from 40° to 65°C, so that the smallest fat particles are obtained at 65°. Ordinarily temperatures above 65° are not used for homogenization. The size of the fat particles also decreases with increased pressure. The effect of homogenization are smaller fat globule size, whiter and more appetizing colour, reduced sensitivity to fat oxidation and fuller bodied flavour and mouth feel. Another necessity for efficient homogenization is the presence of protein. A suggested minimum value 0.2g of casein per gram of fat is recommended. In this process, the average fat globule diameter of 9µm for 4% of milk is reduced to 1.6µm. Homogenisation is carried with two stages with difference in pressure within the range of 20-140MPa. After homogenization milk is further cooled to 40°C (Chandan, 2006).

Inoculation and fermentation

Both cow's milk and soy milk are then inoculated with bacterial cultures. *Streptococcus thermophilus* and *Lactobacillus bulgaricus* are the main starter cultures used for inoculation. The best temperature for growth of these micro-organisms is between 40-45°C. Milk is a nutritionally rich medium which will support the growth of many microorganisms. The primary function of starter culture is to generate lactic acid by fermentation of major sugar in milk i.e. lactose. Soy milk doesn't contain any sugar. So cane sugar or glucose is added to unsweetened soy milk to promote bacterial fermentation as sugar is the food for the bacteria. Fermentation is mainly carried out at same temperature of inoculation for 4-5hr. Due fermentation distinct flavours are developed due to generation of acid. Nevertheless, excessive acid generation by starter organisms because of uncontrolled fermentation will result in shrinkage of the curd. So the pH, temperature should be maintained during fermentation. Lactic acid has preservative effect as well as enhances flavour, special body and texture. The pH of the final yogurt should be between 4.2 to 4.5.As mentioned above stirred yogurts are prepared for yogurt drink. So after fermentation final coagulum is broken by stirring. The texture of stirred yogurt is somewhat like thick cream.

Kiwi juice- (Line-3)

Receiving kiwis

Kiwis are received at large scale. Properly matured, same variety kiwis should be loaded to industry from same supplier. The fruit contains a number of natural materials that contribute to the overall flavour and consistency of the juice including water, sugars (primarily sucrose, fructose, and glucose), organic acids (primarily citric, malic, and tartaric), and flavour compounds. The maturity of fruit is assessed from the color, juice content, TSS, and acidity of the juice. Kiwi fruits coming for juice processing should be as free as possible from rotten fruit, leaves, stalks and other debris.

Sorting

During sorting, the same size kiwis are sorted out in order to maintain uniformity. The rotten, extremely ripened or unripened kiwis are taken out. Any foreign material such as stones, straws should be removed. Sorting could be done manually or mechanically.

Washing

The sorted kiwis are then washed in flowing water in order to remove dust, microbial load. 0/1% $KMNO_4$ is generally used for washing fruits as disinfectant. Finally, the kiwis should be again washed with flowing water to remove traces of disinfectant which might affect the quality of final product.

Drying

After washing, the kiwis are dried by passing over dry air line to completely remove moisture from surface which will affect shelf life of kiwis. Due to presence of moisture the kiwis might start deteriorating instantaneously.

Chilling

Kiwis are chilled in cold room at -18˚C for 30min. Chilled kiwis are very easy for further processing such as peeling, removing middle hard core part. Seeds of these kiwis don't beak easily as broken seeds causes bitterness in final product.

Peeling

The outer unwanted skin of kiwis is removed. The peeling is done mechanically.

Removal of hard core middle part

The middle hard core part of kiwi causes problem in extraction of juice. It causes bitterness as well.

Cutting

Kiwis are cut into small pieces to make extraction easier. The kiwis should be cut into proper small size otherwise big pieces might not get crushed properly during extraction.

Extraction of juice

The juice is extracted from pieces by blending them.

Coarse filtering

Filtering removes fine, colloidal particles from juice. It also helps to discard uncrushed pieces.

Mixing with sterilized water

It is important that water should not affect composition, microbiological, organoleptic properties of juice. Water from different areas have different characteristics such as hard water, soft water. Nevertheless, soft water is usually preferred in juice production. Water should be properly treated using coagulation, reverse osmosis, filteration etc and sterilized as well in order to prevent contamination to final product. Water is boiled at 100˚ C and then cooled to 4˚C.

Standardization

The final parameters of juice such as TSS, acidity, pH should be checked. These parameters should be as follows- TSS-13%, Acidity-0.14%, pH=3.55.

Deaeration

The contact of juice should be avoided with air. Due to presence of air oxidation could take place which will affect quality of juice. After deaeration, if the yogurts are not ready for further mixing juice should be stored at 4˚C.

Mixing

Soy yogurt, cow yogurt, kiwi juice, sugar are blended together. Wide range of stabilisers and acidity regulator are available but high methoxy pectin and citric acid is commonly used. During mixing itself, stabiliser (high methoxy pectin- 0.01-0.5%), citric acid (0.8%) are added. Stabiliser provides appropriate viscosity to drink. It prevents protein from aggregating during storage to reduce phase separation. Citric acid acts as acidity regulator which increases anti oxidation, flavour, shelf life of the product. The main function of citric acid is to maintain pH.

Checking of parameter

After preparation of product the parameters should be measured in order to analyse whether it meets desired values or not. The parameters should be as follows: pH- 4-4.5, MSNF- 8-9.5%. (Goula and Adamopoulos, 2011).

Homogenisation

Homogenisation of final product is carried at pressure of 6MPa. Homogenisation disrupts particles in suspension. It decreases sedimentation to increase viscosity, creates better texture, enhances mouth feel, colour, flavour. Mainly it prevents separation of layers.

Removal of air from bottles and filling

Bottles should be cleaned, free from dust, dirt. Air is removed from bottles by vacuum to prevent oxidation of product. Filling of bottles is then achieved by exhausting of bottles. High speed filling can be achieved by using multi head fillers. Aseptic filling is another good method for filling of yogurt drink which is without any preservative. Such product, if unopened, will remain free from microbiological spoilage. Filling is done in sterilized bottles. Head space should be kept in order to shake before consumption (Ranken et al, 1997)

Sealing of lids and sterilization of sealed bottles

The bottles are then sealed with lids. Person should be there for observation, if bottles are not properly sealed. If filling is not done in aseptic condition, the bottles should be sterilized after filling at 40˚C for2-3 min.

Labelling and packaging

After sealing, the bottles should be properly labelled and packaged .The details of labelling and packaging are explained in detail in next Task 6.

Storage and distribution

The final packaged product is stored at 4˚C and distributed to supermarkets.

Task 2: Design a factory layout design for the production process

There are some principles should be followed in layout design, and generally, a food processing plant shall provide: adequate space for equipment, installations and storage of materials, separation of operations to avoid cross contamination, adequate lightning and ventilation, and Protection against pests. (López-Gómez and Barbosa-Cánovas, 2005).

The general layout and arrangement of rooms within a processing establishment is important in order to minimise the risk of contamination of the final product. A large number of bacteria which will affect the quality of product enter with the raw material. To avoid cross contamination it is essential that raw material is received in a separate area and stored in a separate room. And the sequence of processing operations should be as direct as possible, and base on this principle a "straight line" process flow is considered to be the most efficient. The layout should minimise the risk of recontamination of a semi-processed product.

For the walls, floors and windows in the layout, external walls, roofs, doors and windows should be water-, insect- and rodent-proof. Internal walls should be smooth, flat and resistant to wear and corrosion, impervious, easily cleanable and white or light coloured. Also the floors should be impervious to spillage of product, water and disinfectants, durable to impact, resistant to disinfectants and chemicals used, slip resistant, non-toxic, non-tainting and of good appearance and easy repairable. Floors should be provided with a slope to drains to prevent formation of puddles. All openings such as doors, windows, skylights and ventilators must be adequately screened or constructed and fitted to prevent the entrance of any pests. Lighting should be protected and adequate to carry out plant operations so that broken glass will not be a potential hazard.

Ventilation is basic and important to good food plant sanitation. This will control condensation and help to eliminate any mould growth. Intake air should be filtered and the air in the finished product area should be maintained at positive pressure. Clear physical segregation between "clean" and "unclean" areas is important. "Unclean" areas are those where raw material is handled, and often a cleaning operation (wash) or a heat treatment is marking the point, where the process flow goes from "unclean" to "clean" areas. Also cooled room must be separated from hot room where cooking, smoking, retorting etc. are taking place. Dry rooms must be separated from wet rooms and separate rooms must be provided for waste material, chemicals, packaging materials and wood. The separation between the clean and unclean areas must be complete, not only the space but also the human. There should be no human traffic between these areas, and equipment used in the unclean areas should never be used in the clean area, which means that there should also be separate wash and hygiene facilities for equipment

and personnel in these areas. The personnel should wear different coloured protective clothing for different operations (e.g. white in the clean and blue in the unclean) to identify (López-Gómez and Barbosa-Cánovas, 2005).

It is also very important to ensure that there are no interruptions and no "dead ends" in the product flow, where semi processed material can accumulate and remain for a long time at ambient temperature. Time/temperature conditions for products during processing are important critical control points (CCPs) in order to prevent bacterial growth. This means that a steady and uninterrupted flow of all products is necessary in order to have full control of this critical point. If any delays in product flow are necessary, the products should be kept chilled. According to the demands of soya yoghurt drinking product processing, connecting with actual processes, the following buildings need to be considered.

（1） Raw material warehouse

The raw material warehouse is used for raw material storage and reception, such as raw milk, soya milk, sugar, fruits, etc. The area of raw material warehouse is designed as 1000m^2. The specific layout of warehouse is based on the actual situation.

（2） Production area

Production department is mainly designed for processing. The primary production flow is as follows: materials should be following standardization, adding ingredients, filtering, pro- heating, putting in homogenate, sterilizing, cooling down, inoculating, culturing, fermentation, cooling down again， and mixing. Among them, fermentation is the step, which consumes the most energy and also affects most on the quality of the yoghurt.

（3） Packaging workshop

Package materials reception and storage plant and packaging workshop are included in this part. The height of the floor of packaging workshop should be as the same as the standard of low temperature warehouse. The requirements of the department should be same as production department and adding ceiling to the top and insulation material surround the walls. In addition there should be a special door liking to packaging materials library. After packaging, the products should be sent to next department directly. The area is 1000m^2.

（4） Refrigeration plant

Refrigerated plant, which is next to the main process area and electricity substation room, used for storage of processed and packaged yogurt or juice products. According to the basic design requirements and demands of cold storage warehouse, the cement floor of this department should be thicken and reserved holes. In addition, the cold storage warehouse should be separated into two parts, which are linked by a door. The use of cold storage warehouse should follow the actual needs. Using double cold storage warehouses mainly to reduce the cost of energy, and can be easy to manage, so that the actual cost will be reduced. The capacity of cold storage warehouse is 15t. In normal condition, it can store about 1t products per square meter, the whole area of which is 50m^2.

（5） Laboratory

Laboratory should be in one side of the building, which is next to raw material warehouse and main production area. This place is used for testing the quality of the raw materials and the final products. The area of laboratory should be 80m^2.

（6） Locker room and toilet

Locker rooms and toilets should be put on the way to departments, which are separated for male and female and people doing different kind of work avoiding cross-contamination. The area should be 120m^2.

（7） Electricity substation room and machine repair shop

Distribution room and machine repair shop, which are approaching to energy centre. The area should be 100m^2.

（8） Reserving area

Reserving area is used for designing wastewater Pond, the area of which is 200m^2.

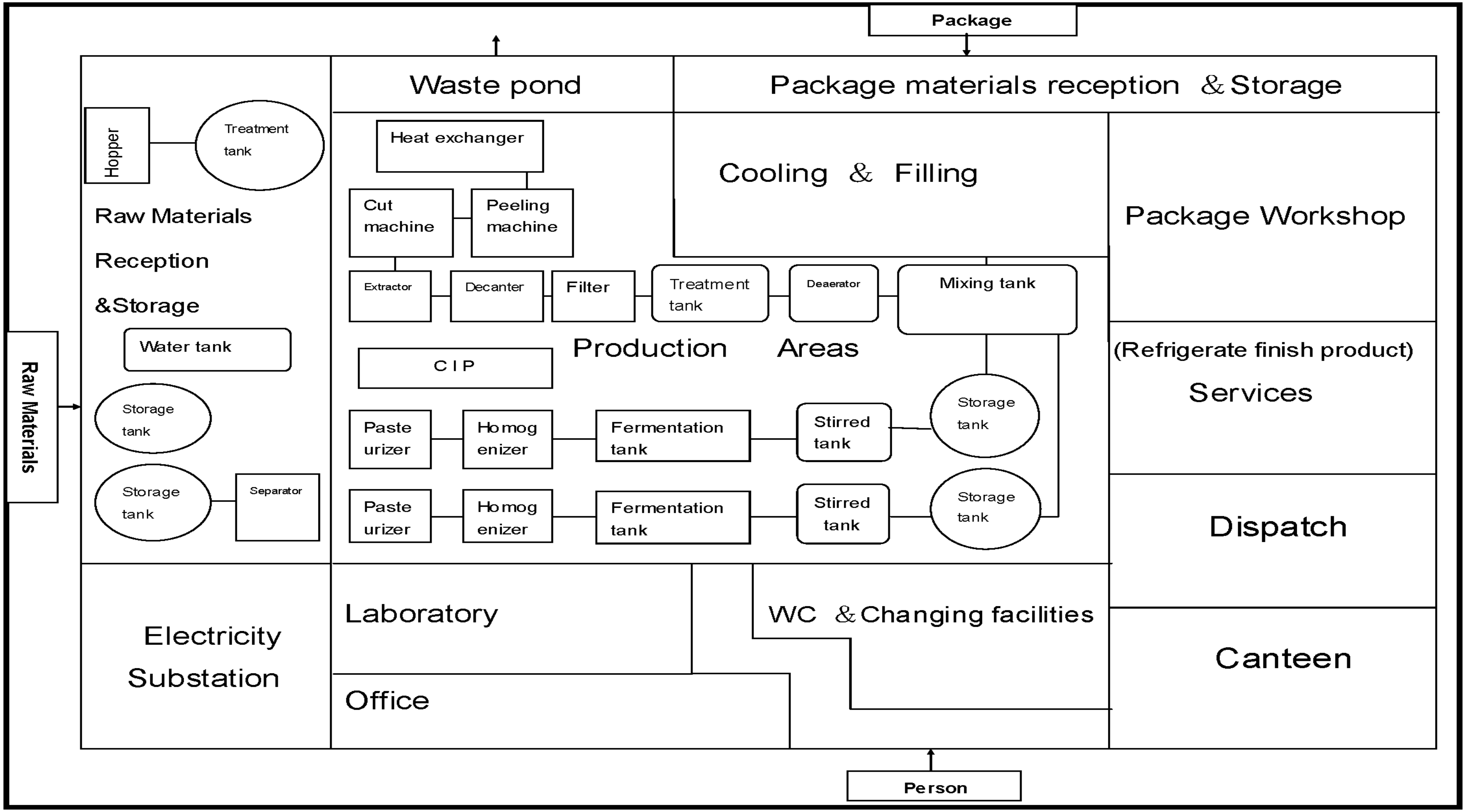


Figure 3 Factory layout design

Task 3: Select process and ancillary equipment required to meet the define production requirement

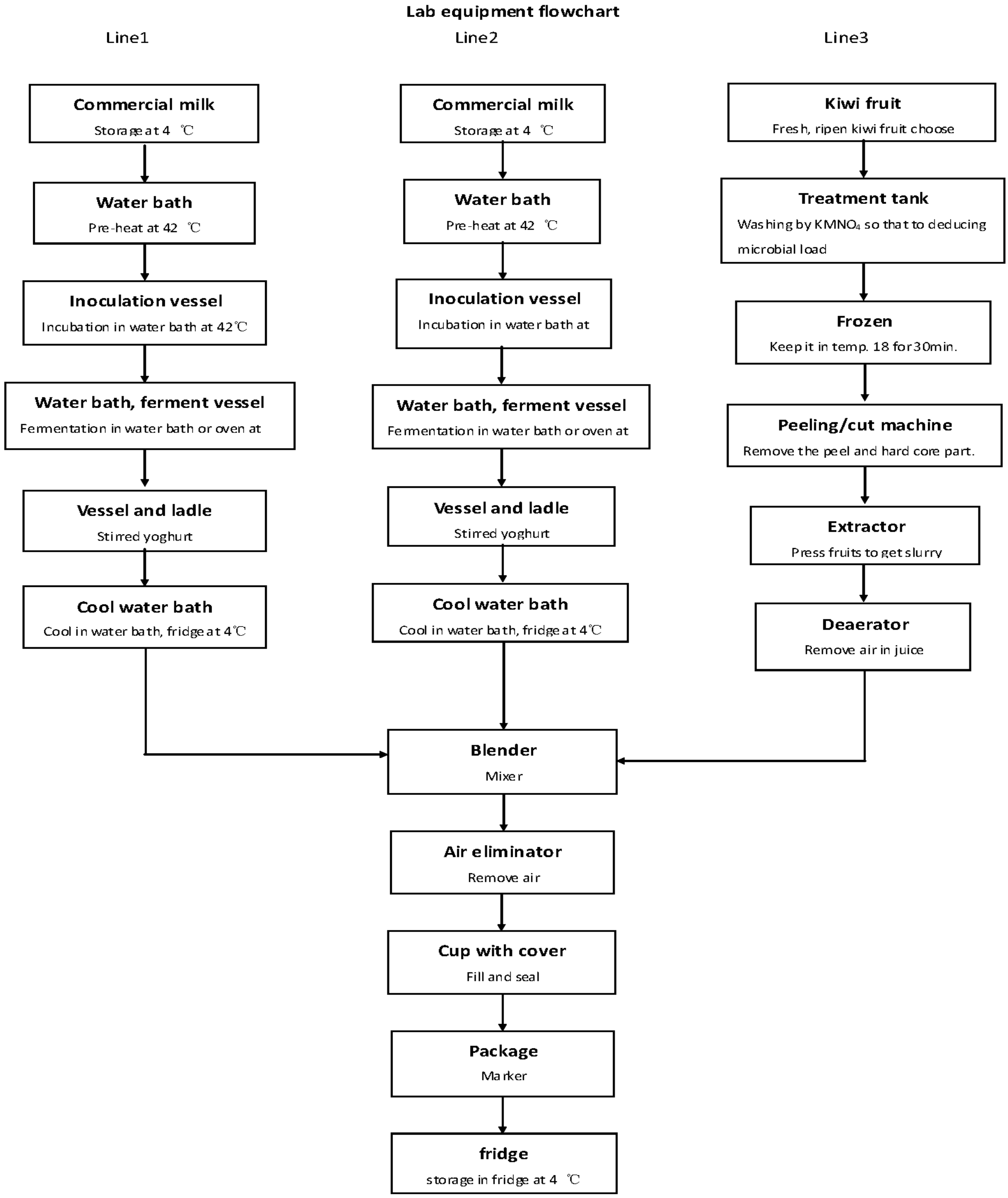


Figure 4 Laboratory equipment flow chart

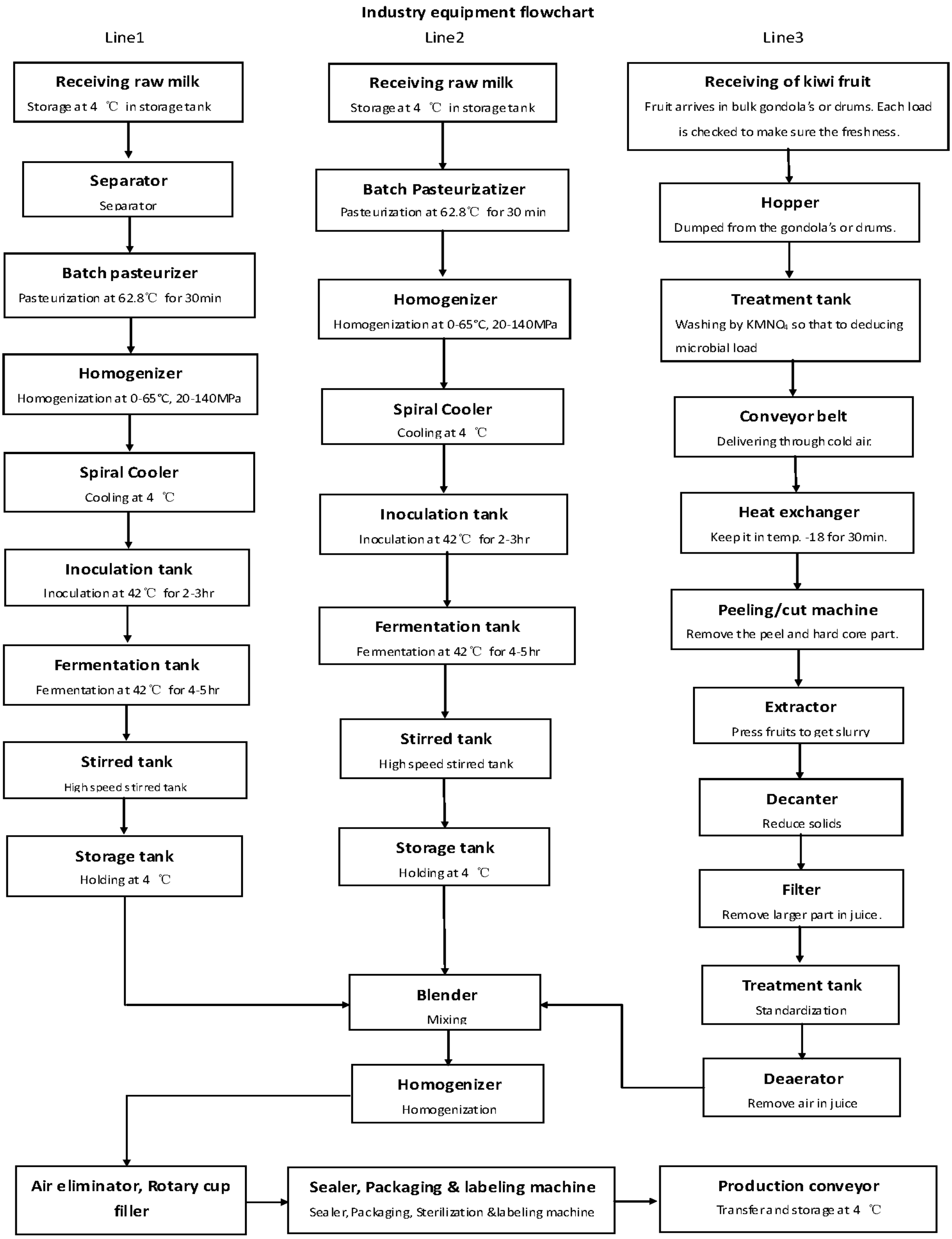


Figure 5 Industrial equipment flow chart

Equipment description

The selections of the equipments are based on the production of the drinking yogurt and the capacity of the equipments. The estimated plan of daily production is 10,000 units where each unit comprise of 250ml.

1. Tanks

Storage tanks are needed for the storage of milk after the milk reception and the capacity required is at least 2500L. The storage tanks made by M.G.T. LTD can be used to fulfil this requirement (2010). The temperature should be controlled around 4°C. Fermentation tank is needed in fermentation processing. Fermentation tank is water jacketed and warm water at 40-45°C is circulated during the fermentation period, followed by cold or chilled tanks .The fermentation tank made by M.G.T. LTD could be used with the size of 2500L. Mixing tanks, stirred tanks and other tanks are also needed with the capacity of 2500L.

2. Separator

The TS-500-O separator made by TESSA Rec Group LTD. can be used to separate the milk with a rate of 500L per hour. The fat percentage ranges from 0% to 3.5% (2011).

3. Batch Pasteurizer

The Batch Pasteuriser produced by TESSA Rec Group LTD. could be used in the plant. The capacity of this pasteurizer is 500-1,000 L/Batch. The machine is automatically controlled and it consists of Iron Panel, Temperature Controller, Hot Water Controller, Printed Output Product Controller, Pump Activation and the structure is SS-304 (2011).

4. Homogenizer

The TH-025 homogenizer produced by TESSA Rec Group LTD. is made of Stainless Steel and arrive complete with Input and Output options, Automatic Control Board and Accessories. The Production Rate is 500L per hour. The power is 5.5kw and the operating pressure varies from 20 to 25 kpa. The main material parts of the homogenizer are ss304 (2011). The equipment should work at 0-65°C.

5. Cooling system

The cooling system (TC-6000) made by TESSA Rec Group LTD could be used to cool the milk at 4 ℃.The system consists of an Ice Water Unit and a Plate Heat Exchanger. The Production Rate is 6,000 kCal/hr .The working temperature ranges from 2-4°C. The refrigeration is R22 and the compressor is Copeland cross (2011).

6. Filling machine

The bottle filling machines have different sizes .The Dogaseptic series are manufactured to fulfil the specific demand of 500L/hour (Benz&Hilgers Gmbh,Germany).The capacity of production is 2500L daily and we choose the 250ml packs as the base unit .This machine has the ability to finish the filling and sealing at the same time.

7. Blender

Gasti DOGAmix 60 can be used to mix the fruit juice and the yogurt (Benz&Hilgers Gmbh,Germany).

8. Kiwi peeler

The Automatic kiwi and mango peeler (OP 30K) made by ABL S.r.l. could be used to peel the skin of the kiwi .This machine can deal with 30 fruit per minute and do the cutting of the fruit at the same time (2011).

9. Juice Extractor

Fruit juice extractor (model LZ-105 made by Zhangjiagang Renda Machinery Co., Ltd) could be used to press fruits to get slurry with a maximum capacity of 1.5T/hour (2011).

10. Juice Filter

The Motorized Round Vibrating Filter Machine for Fresh Kiwi Fruit Juice (model 600 by Xinxiang Tongxin Machinery Limited Liability Company) could be used with 0.55 kw motor power (2011) to remove the larger particles remain in juice.

11. Decanter

The screenbowl centrifuge is used to extract solid particles from liquid and the machine with the size of 36" x 72" made by Decanter Machine, Inc.

12. Deaerator

FrymaKoruma Vacuum Deaerating Unit type VE made by Romaco Group could be used to remove air in juice. The usable volume of VE is 1200 L and the power is 24 kw.

13. Labelling Machine

The labelling machine always works together with the filling machine and have the same working time.

14. Heat Exchanger

Counter Plate heat exchanger is preferred in the production as it has high working efficiency and less heat loss.

15. CIP System

The CIP system include 1 control panel, tanks for detergent solutions ,liquid ring pumps used as return pumps for cleaning, plate heat exchanger, centrifugal pump, filter and steam controller. This system offers the cleaning of the equipment without disassembles.

Task 4: Using design of experiments for conducting product and process optimization

Screening experiment

A screening experiment is considered as a systematic approach in the process of identification of the key parameters (factors) which largely affect the response variables. That could be the magnitude of the alteration of the response variable when each factor is changed and also the alteration of all the factors that could have a different effect than each single factor modifications. The information can be gained from a screening experiment can be valuable in the identification of the key factors in the process. What is more, they can be useful in the determination of the direction of the proper factors' adjustment and in the identification of the factors that should be controlled during production, in order to achieve 'high performance' (Douglas 2009).

The experimental design in a screening experiment involves all the factors at two levels: upper and lower. In the case of the 'Soya yogurt drink with kiwi flavour', the four factors include the water, kiwi juice, sugar and cow's yogurt percentage. Two limits were set for all the four factors (**Table 1)** and all possible combinations were examined (2^4=16 in total). These ranges were selected according to technical specifications and after a preliminary research on similar products in the market. The sixteen samples were evaluated for four selected sensory attributes defined by the user needs-and-wants study on Unit 2. These attributes were consisted of thickness, milk flavour, kiwi flavour and sweetness where thickness was correlated with the percentage of water, milk flavour to the percentage of cow's yogurt and kiwi flavour to the percentage of kiwi juice. In addition, the samples were evaluated for overall acceptability by 32 untrained assessors. A balanced complete block was used and since the number of samples was too large, the test was divided into two sessions, 8 samples per session. Both cow's yogurt and kiwis were bought directly from the supermarket. The cow's yogurt was 'Morrissons' brand, 1.5 % fats.

Table 1. Screening experiment: factors' limits

Factor	**Lower limit**	**Upper limit**
% cow's yogurt	20	50
% water	13	34
% kiwi juice	8	15
% sugar	6	15

Statistical analysis

The statistical analysis of the results was accomplished using the R project. Specifically, the analysis begun with the Tukey's test for additivity in order to test the hypothesis that there is no interaction between Assessors and Samples, following by Single factor within-subjects analysis of variance (ANOVA). It is testing the null hypothesis of

equality of mean acceptability between samples, H_0: $\mu_1=\mu_2=\mu_3=\mu_n$, (n=16) against the alternative hypothesis that not all the samples have the same mean acceptability, H_0: not all μ_n are equal. These two tests were conducted for all the four attributes and for overall acceptability as well. Only for thickness attribute the results were significant (for significance level 5%) and therefore the analysis continued with Friedman's two way analysis of variance to analyse the data from the rank preference test. Tukey's honestly significant difference by ranks was then conducted as the results from Friedman's test indicated that at least one comparison between rank sums is significantly different. Friedman's is testing the null hypothesis of equality of rank totals for acceptability between samples, H_0: $\Sigma R_1= \Sigma R_2 =\Sigma R_3= \Sigma R_n$ (n-16) against the alternative hypothesis that not all the samples have the same rank totals for acceptability, H_0: not all ΣR_4 are equal.

Furthermore, the response surface methodology- 2^k Factorial design was used for the completion of the analysis. It is a useful tool in the early stages of experimental work especially in cases that many factors are being investigated (Douglas 2009). According to the results, sweetness was the only attribute which seem to be non-significantly accepted. Therefore, the mean values (calculated from the software Compusense® five) were also investigated showing that samples in upper percentage of sugar got higher score than samples with lower limit. As a result, 10% of sugar was considered as the most acceptable for using it in the optimisation (keep it constant).

In addition, as for thickness attribute, the response surface results showed that assessors prefer high level of water and consequently a thinner product. Nevertheless, according to the technical specifications and by the legislation, the solid content should be 8-9.5%, so the highest amount of water used in the final product should not exceed the 20%. Thus, it was decided also to keep it constant in 20% in the optimisation procedure.

Finally, the results for the rest two factors, the percentage of kiwi juice and cow's yogurt, indicated that assessors prefer both of them in low levels. For that reason, it was decided to be examined in three levels in the optimisation experiment. Since there is a fraction on the lower limit of kiwi juice that can be used (according to technical specifications), the lowest limit for the optimisation experiment was set as 8%, followed by 10% and 12%. The equivalent levels for the percentage of cow's yogurt were set to 7.2% (lower), 14.7% (medium) and 22.2% (high).

Optimisation experiment

After the screening, an optimisation experiment was conducted in order to determine the optimum region and also the most important factors to be identified in order to achieve the best possible response. As mentioned, the objective in this optimisation experiment was to minimize both the percentage of cow's yogurt and the percentage of kiwi juice in the final product, which consist the two main factors based on the screening test. On the other hand, the percentage of both sugar and water was kept constant at 10% and 20% respectively. The three levels of the two examined factors (% cow's yogurt, % kiwi juice) are presented on **Table 2.**

Table 2. Optimisation experiment, factors' limits

Factor	**Lower level (L)**	**Medium level (M)**	**High level (H)**
% cow's yogurt	7.2	14.7	22.2
% kiwi juice	8	10	15

Statistical analysis

The statistical analysis of the results was accomplished using the R project. A single factor within-subjects analysis of variance (ANOVA) was used to determine if there are any significant differences between the test samples at significance level of 5%. If there was a departure from normality, then the raw data converted into ranks and the Friedman test was performed. In case where the null hypothesis for the ANOVA test or the Friedman test was rejected for the sample factor, then Tukey's honestly significant difference or the HSD ranks was used to determine any significant differences between all samples. In addition, the two-way ANOVA was conducted to

analyse data from a completely randomised design. Finally, the response surface methodology- 3^k Factorial design was used for the completion of the analysis.

Three different models were used to determine the optimal region for both kiwi and milk flavour as following: i) FO (First order) ii) FO (First order) + TWI (Two way interaction), iii) SO (second order). The best model for each factor was chosen by checking the p value and lack of fit. In addition, plots were plotted by using the best model followed by analysis for the best region. The statistical analysis result of optimisation using 3D contour plots for kiwi flavour, milk flavour and overall acceptability are discussed further.

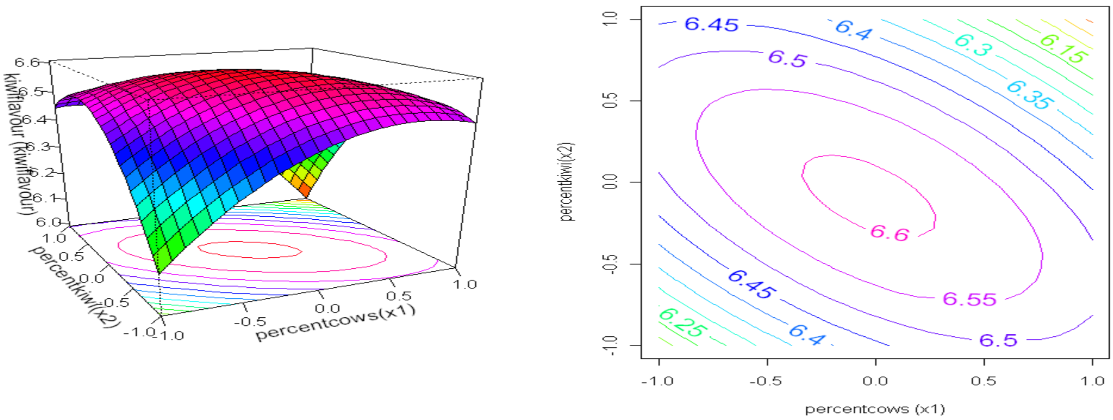


Figure 6. Response surface plot for Kiwi flavor, (X1= % cow's yogurt, X2=% kiwi juice)

Initially, the residuals of kiwi flavour were plotted and found that two assessors didn't reply correctly. Therefore, those assessors were discarded from data. The best model for kiwi flavour was found to be SO (second order). By using this model, the 3D graphs were plotted to find out the interaction between percentage of cow's yogurt and percentage of kiwi juice. The 3D contour plots indicated that the higher score achieved for the kiwi flavour was between 6.6-6.7. Nevertheless, according to the standards, the percentage of cow's yogurt and kiwi juice can't be reduced beyond the lower limit. Hence, the optimal region for cow's yogurt and kiwi juice is considered to be 14.5% and 9% respectively.

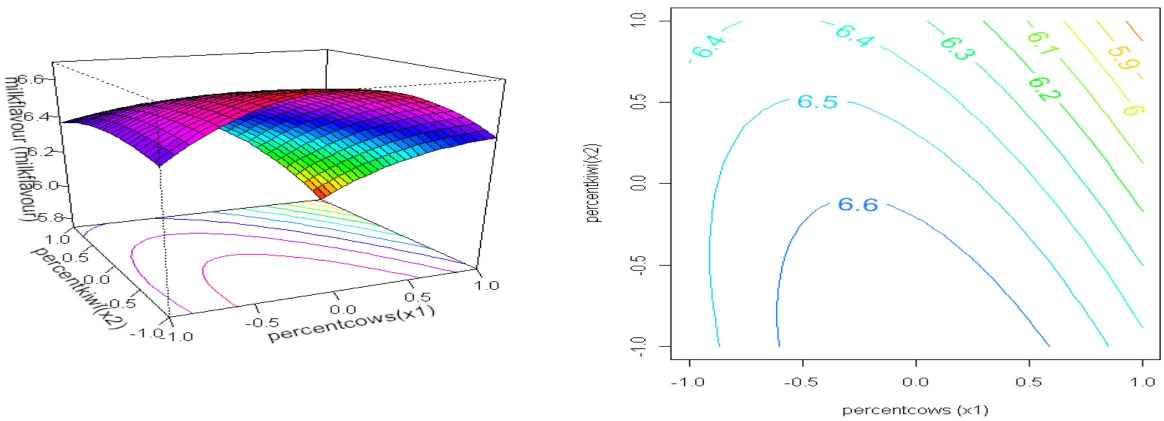


Figure 7. Response surface plot for milk flavor, (X1= % cow's yogurt, X2=% kiwi juice)

As for the milk flavour, it can be seen from the residual plots that all the assessors replied correctly. SO (second order) model seemed to be the best and therefore, the contour plots were plotted according to this model. Plots indicated that the optimal region for milk flavour is the lower percentage of kiwi juice and medium percentage of cow's yogurt. The higher score gained for milk flavour was between 6.6-6.8. Plots strongly show that there is definite interaction between percentage of cow's yogurt and kiwi juice with respect to the milk flavour.

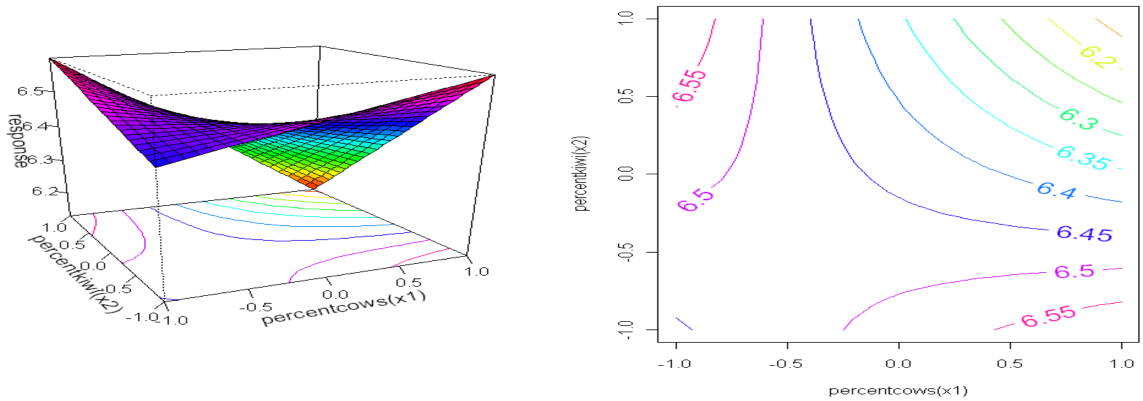


Figure 8. Response surface plot for overall acceptability, (X1= % cow's yogurt, X2=% kiwi juice)

The analysis of overall acceptability had also been conducted in order the final decision over optimal region for kiwi flavour and milk flavour to be taken. The residual plots have shown that 2 assessors didn't reply correctly, thus they discarded. FO (First order) + TWI (Two way interaction) was the best model. Plots strongly suggest that the optimal region can be achieved with two different combinations, a) with low percentage of kiwi juice and high percentage of cow's yogurt b) low percentage of cow's yogurt and high percentage of kiwi juice. The higher score was between 6.5-6.7. In addition, it is seemed that there is interaction between percentage cows yogurt and percentage kiwi juice.

In conclusion, it could be said that, the best formulation for percentage of kiwi juice and cow's yogurt is at 14.5% and 9% respectively. However, some enhancements can be done in the Unit IV in order to get higher scores i.e to reach 7 in the 9-point scale. These enhancements should mainly involve the alteration of sugar percentage, since it was the only attribute for which t obtained results were not significant .Also, sweetness had no interaction with the other attributes. Moreover, if more sensory tests have to be done, then the number of samples should be as minimum as possible. That's because assessors seem to rate in more proper way when the number of samples is smaller.

Task 5: Product acceptability and preference

Preference test was conducted in order to give an indication of whether the formulated product is acceptable to the consumer. The main objective was to minimize the percentage of cow's yogurt and maximise the percentage of kiwi juice in the final product. Therefore, these two factors were examined in three levels (Low-L, Medium-M, High-H) in all possible combinations (LL, LM, LH, ML, MM, MH, HL, HM, HH). The percentage of both sugar and water kept constant at 10% and 20% respectively. Thus, nine samples were examined by 54 untrained assessors in a single session in sensory panel room without any discussion. Number of assessors was determined by using complete block design in Compusense® five. All the assessors were instructed for the test procedures before the testing samples. In addition, all the assessors were provided with a consent form prior to the test and were asked to sign it only if they are not allergic to any product ingredient. The questionnaire was designed using the

software Compusense® five and the responses were collected on the computer. All the four attributes (sweetness, kiwi and milk flavour, thickness) as well as the overall acceptability were assessed. A preference test with 9-point hedonic scale (**Table 3**) was conducted. All the test conditions were same as the screening experiment.

Table 3. The 9-point hedonic scale

1	2	3	4	5	6	7	8	9
Dislike extremely	Dislike very much	Dislike medium	Dislike slightly	Not like or dislike	Like slightly	Like medium	Like very much	Like extremely

Sample portions of 30mL were served cold (~4^0C) in clear plastic glasses assigned a three- digit random number, tasting from left to the right. Also, samples were presented simultaneously in balance, random order according to the randomised block design. An appropriate 'Cleansing' (mineral water) was provided to reduce any residual flavour. All samples were prepared on the same day of the test, with the same way, using the same raw materials and under the same conditions.

In 3k factorial design, x1 was percentage of cow's yogurt and x2 was percentage of kiwi juice. There was interaction between these two factors with respect to kiwi flavour, milk flavour and overall acceptability. The result can suggest that the best formulation for the percentage of kiwi juice and cow's yogurt is 14.5% and 9% respectively. The product is accepted by consumers with score of 6.5-6.7. Nevertheless, some efforts need to be taken to achieve higher acceptability by consumers.

Task 6: Determine product formulations and process specifications

Table 4. Raw material specification for lab scale

Raw material (For 1000g drink)	Specification	Quantity
Cows yogurt	"Morrisons" low fat (1.5%)	14.5% (145gm)
Soy yogurt	"Alpro"	47.5% (475 gm)
Water	Sterilized tap water from lab	20% (200gm)
Kiwi	"Morrisons" mature	9% (90gm)
Sugar	" Morrisons" granulated sugar	10% (100gm)

The specifications illustrated in **Table 4** are for 1000gm of Soy yogurt drink with kiwi flavour which was made at laboratory scale. All the raw material for drink could be bought from supermarket .Nevertheless, when production is at industrial scale, all the raw materials such as cow's milk, soy milk, kiwis, sugar can be provided by supplier. Water will be supplied from wells or any other source near to industry. Water treatment plant should be there in order to purify it. Quality parameters (microbiological and chemical) of all raw materials will be checked at the receiving point. The material which doesn't meet the standardised parameters will be rejected. Cow's milk and soy milk should be processed within 48 hours. All necessary hygienic conditions should be maintained in storage of raw material. Also, all tanks used for storage should be properly sanitized. Humidity conditions should be checked in storage of sugar and kiwis.

There will be three processing lines in industry: i) soy yogurt, ii) cows yogurt, iii) kiwi juice. Soy milk and cow's milk should be pasteurised at 68.5˚C for 30 min. Homogenisation should be carried out at 40-65˚C at pressure of 20-140MPa. After inoculation, fermentation should be carried out at 40-45˚C for 4-5 hours. Kiwis are kept in cold room at -18C for 30min. Kiwi juice is made with blending of pieces for 2-3 min. Sterilized water (boiling at 100 ^{o} C) is added to juice. Cows yogurt, soy yogurt, kiwi juice should be chilled at 4˚C before mixing. The proportions should be 47.5% for soy yogurt, 14.5 % for cow's yogurt, 10% for sugar, 20% for water and 9% for kiwis. All the ingredients will be mixed for 2-3 min to get desired drink. Finally, the yogurt drink is stored at 4˚C.

Soy yogurt drink contains total solid content- 20%, pH- 4.2-4.5., fat %- 1.5-1.7%. The nutritional value of the product will be determined in further stage.

Primary, secondary and tertiary package are needed for soy yogurt drink. Yogurt drink will be filled in PET bottles of 250 ml. Bottles will be sealed with tight lids in order to avoid contact with air. Nutritional information, name of product, manufacturers name, expiry date and ingredients will all be clearly defined on the bottle. An attractive picture of yogurt and kiwi on bottle will give good visual appearance to the consumer. Eight bottles of 250ml will be placed in one carton which will show the number of bottles and name of the product. Cartons will be put into crates for storage and distribution. In further stage, the effect of packaging on shelf life will be analysed.

Task 7: Determine if the production process is in compliance with relevant national, European and international regulations

The legislation for Soy yogurt drink mainly concerns with the legal definition of yogurt products, ingredients, bacterial cultures, requirements of main processing stage and labelling regulations.

The Codex Standard for fermented milk (243-2003) applies to all the fermented milks that are directly consumed or use for further processing. The flavoured fermented milk should not contain more than 15% of fruit. Composition requirements for fermented milk and yogurt are listed as follows: the minimum milk protein in fermented milk and yogurt should be 2.7%, the milk fat in fermented milk should be less than 10% and should be less than 15% in yogurt. In addition, the minimum acidity (expressed as the percentage of lactic acid) of fermented milk should be 0.3% and 0.6% in yogurt. The minimum sum of the microorganisms constituting started culture should be 10^7 in both fermented milk and yogurt (Chandan 2006).

Yogurt can be legally described as any fermented milk product that contains the characteristic bacterial cultures *Lactobacillus bulgaricus* and *Streptococcus thermophilus*. According to regulation, all yogurt products must contain at least 8.0% to 9.5% solids not fat, with generally low fat around 0.5% and contains a substantial amount of sugar (8% to 12%). The average finished yogurt drink should have a pH of 4.0 to 4.5. Some products may contain maximum 30% of fruit. The level of stabilizer varies depending upon the choice of hydrocolloid, but usually ranges from 0.01% to 0.5% (The Food Additives (Scotland) Regulations, 2009).

The food safety and quality is the first important aspect of any food material to make sure it is safe for human. To ensure the safety there should not be contamination during the yogurt processing, and keep the product high in quality. All the ingredients of final product should be handled properly to prevent any contamination and growth of any harmful bacteria. The first step to ensure safety and quality in production could be initiated with the washing of the kiwis. Moreover, the whole process of kiwi juice extraction and yogurt fermentation relies on accurate temperatures to ensure that no pathogens could be found in the final product. The cooling time is also important in order to avoid any contamination of the bacterial growth in the yogurt drink product (Food Standards Agency, 2011).

Pasteurization is another important stage to avoid the contamination of pathogens from raw material and to maintain the high quality of the final product. According to the SUBSIDIARY LEGISLATION 449.10(1978), there are two specific condition for pasteurization treatment: i) the temperature should not be less than 71.7°C (161° F) and the duration of treatment should not be less than 15 seconds and thereafter should be cooled to a temperature of not more than 10 °C (50° F) immediately after pasteurisation, ii) temperature should be not less than 62.8°(145° F) and the duration of treatment should not be less than 30 minutes, and thereafter cooled to a temperature of not more than 10 °C (50° F) immediately after heat treatment .The second treatment was could be performed on the industrial scale of soya yogurt drink to minimize the contamination.

With respect to the labelling of the yogurt drink, according to the Food Standards Agency's Food Standards Training Manual (2007), label of fermented milk must contain list of ingredients. Moreover, list of ingredients should comply with Food Labelling regulation (1996).

Task 8:- Plan of action for unit IV

Task-1	Uncompleted work from unit III found in product and process specification report. e.g analyse nutritional content of soy yogurt drink.
Task 2	Conduct commercial product test using test market by conducting consumer sensory study to confirm if final product meets expectations of the consumer.
Task 3	Determine intrinsic and extrinsic factors affecting shelf life which is important to determine used by date, safety of product and propose methods to control and monitor shelf life.
Task-4	Propose adequate packaging that meet food quality and safety requirements with the help of shelf life requirement.
Task-5	Demonstrate that the product and its production process is in compliance with national and EU labelling legislation and food safety requirements.
Task-6	- Propose prerequisite programme for GMP and GHP with the help of FSA, FDA, Codex alimentarius Commission
Task-7	Conduct HACCP analysis of production process
Task-8	Propose plan for the quality control of raw material and final product as well as possible solutions for on line or in process monitoring.

List of deliverables with an agreed line for completion-

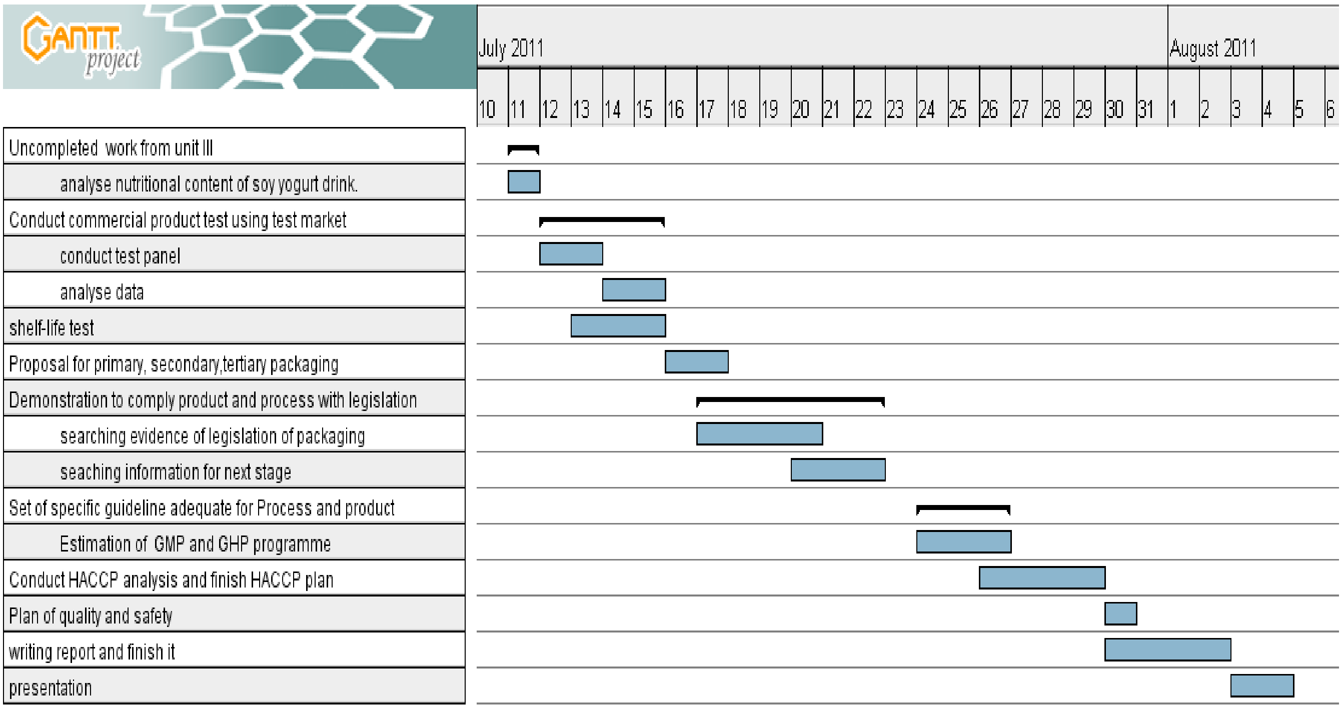
Following is the list of deliverables getting after conducting above mentioned tasks with agreed date of completion-

Task	Deliverables	Date of completion
Task 1	Nutritional composition of the final product	12/7/11
Task 2	Results or data of commercial product test	14/7/11
Task 3	shelf life	15/7/11
Task 4	Proposal for primary, secondary, tertiary packaging	18/7/11
Task 5	Degree of compliance of production process with UK and EU legislation	22/7/11
Task 6	Set of specific guideline adequate for Process and product	26/7/11
	10 page manual of GMP and GHP	
Task 7	HACCP plan	28/7/11
Task 8	Plan of quality and safety	30/7/11

List of milestones

Milestone	**Completion date**
Analysis of commercial product test and confirmation of achievement of original WHATs	17/7/11
Demonstration to comply product and process with legislation	23/7/11
Estimation of GMP and GHP programme	27/7/11
Conduct HACCP analysis	29/7/11
Completion of 20 page report	3/8/11

Presentation	5/8/11



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